World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Check for updates

Evaluation of the energy potential of solar irradiation and wind speed in the Forécariah Prefecture, Guinea

Yacouba CAMARA [1,*], Amadou Lamarana BAH [2], Tiadiane Alpha CAMARA [2], Ibrahima Sory Yanssané [2] and Mohamed FOFANA [3]

[1] *Energy Department, Higher Institute of Technology of Mamou, Mamou, Guinea.*
[2] *Laboratory of Teaching and Research in Applied Energy, Gamal Abdel Nasser University of Conakry, Conakry, Guinea.*
[3] *Department of Mechanical Engineering, Gamal Abdel Nasser University of Conakry, Conakry, Guinea.*

World Journal of Advanced Research and Reviews, 2024, 23(03), 1692–1698

Publication history: Received on 04 August 2024; revised on 12 September 2024; accepted on 14 September 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.23.3.2816

Abstract

The objective of this study is to assess the energy potential of solar and wind resources in the Forécariah prefecture in Guinea, taking into account average sunshine and wind speeds. The study aims to determine the renewable energy production capacity in order to contribute to the sustainable energy development of the region.

The methodology adopted includes the collection of meteorological data over several years (21 years), focusing on solar irradiation and wind speed in the region. Calculation models were used to estimate the possible solar and wind power, as well as the number of wind turbines required. The wind rose was also studied to optimize the orientation of the wind turbines. During this study we obtained several results, the main ones being: maximum monthly sunshine (6.2 W/m^2), minimum monthly sunshine (3.9 W/m^2), maximum annual sunshine (5.34 W/m^2), minimum annual sunshine (5.03 W/m^2), maximum monthly average speed (3.8 m/s), minimum monthly average speed (1.8 m/s), maximum annual average speed (3 m/s), minimum annual average speed (2.6 m/s), installed solar power (20 MW), installed wind power (2 MW) with 82 wind turbines and the wind rose indicating the wind direction from the southwest to the northwest. These results show a significant energy potential for the production of electricity from renewable energies in the prefecture of Forécariah, Guinea.

Keywords: Evaluation; Energy potential; Solar; Wind; Forécariah; Guinea

1. Introduction

Meteorological data are crucial inputs in energy system models. Wind speed, irradiation and temperature are used to estimate the energy production of renewable generators such as photovoltaics (PV) or wind turbines installed in a given location. In recent years, increasing attention has been paid to models focused on large-scale renewable energy systems [1-3]. The validity of the results obtained by these models is most likely significantly affected by the quality of the input data. Indeed, measurements are rarely available in a desired spatial density and therefore often inadequate for simulations (e.g. wind speed data are only provided at 10 meters above ground, while a modern wind turbine has a hub height often exceeding 100 meters). Furthermore, ground measurements often tend to be incomplete (due to equipment malfunction or shutdown of a given measuring station). In such situations, data from satellite measurements and various reanalyses are applied. These data are characterized by a relatively long temporal coverage (sufficient to account for interannual variability of wind and solar energy in modeling) and a good spatial resolution and extent (usually available for the whole Earth) [4-8]. Meteorological data play an important role in estimating renewable energy potentials worldwide.

* Corresponding author: Yacouba CAMARA

The demand for renewable energy is increasing rapidly [9-10] due to global efforts to reduce CO2 emissions. Solar and wind energy play a promising role for both developed and developing countries and are considered as the most promising renewable energy sources due to their advantages [11, 12, 13]. First of all, both of these energy sources are clean, as they can provide electricity without emitting greenhouse gases and toxic gases such as CO2 and NOx. In addition, they can have positive effects from an economic point of view, not only because after the initial investment, they reduce electricity bills, but also because the renewable energy sector has the potential to create new jobs. Furthermore, solar and wind technologies are relatively easy to install on rooftops for solar and on mountains and along sea coasts for wind, so they can provide a means of generating clean electricity in rural areas [14].

Despite the advantages of solar and wind energy, current global solar production represents only a tiny fraction of what is potentially available to develop, since solar energy covers only 0.05% of the total primary energy supply [14]. To change this situation, researchers must provide policymakers with tools that allow them to easily assess the amount of electricity that can potentially be produced from solar and wind energy by their country, compared to what is currently produced and consumed. This requires a comprehensive estimate of each country's potential to produce electricity from centralized and decentralized solar and wind installations.

Guinea has considerable hydroelectric potential (estimated at more than 6,000 MW) whose developed potential has reached 817.35 MW with a coverage rate that increased from 21% in 2015 to 47% in 2022 for a coverage of regional capitals limited to 7%. The potential for solar and wind energy is significant but largely underexploited, due to the lack of an ambitious program for the use of these renewable energy sources. It is in order to make our modest contribution to the use of renewable energy in decentralized areas that we have chosen the research topic entitled: Estimation of the energy potential of solar irradiation and wind speed in the Forécariah Prefecture in the Republic of Guinea.

2. Material and methods

2.1. Presentation of the study area

The prefecture of Forécariah is located in the Kindia region of the Republic of Guinea, approximately 100 km southeast of the capital, Conakry. It covers an area of approximately 4,200 km^2 and is bordered by:

- To the north by the prefectures of Kindia and Coyah;
- To the east by the prefecture of Dubréka;
- To the south by Sierra Leone;
- To the west by the Atlantic Ocean.

Forécariah is distinguished by its humid tropical climate, marked by two main seasons: the rainy season, which extends from May to November, and the dry season, from December to April. Annual rainfall is abundant, often between 2,000 and 3,000 mm, favoring lush vegetation and agricultural development in the region.

The prefecture's relief is mostly flat, with some isolated hills, and the proximity of the Atlantic Ocean influences its climate, favoring moderate temperatures. This geography offers a favorable framework for the exploitation of renewable energies, in particular solar energy thanks to regular sunshine, as well as wind potential near the coast.

2.2. Working tools

As part of this study, we collected data on solar irradiation, wind speed and temperature in the Forécariah Prefecture as basic elements to conduct this research.

The methodology adopted for the implementation of this study consists of collecting meteorological data from the study area for a first time and then proceeding to the evaluation of energy potentials. The meteorological data collected for this study are: wind speeds, sunshine and temperatures for an observation period of 21 years (2000-2020).

To estimate the energy potential of solar irradiation and wind speed in the Forécariah prefecture in Guinea, it is essential to have accurate and region-specific meteorological data.

2.3. Assessment of the solar potential of the Forécariah area

To estimate the solar energy potential of the Forécariah area, we must take into account certain factors, including:

- Guinea has a high solar potential, with an average solar irradiation of 4.8 $kWh/m^2/day$ in several regions;
- Forécariah, located near the coast, could have a similar or slightly lower solar irradiation compared to inland areas due to maritime effects, but it is likely to be between 4 and 5 $kWh/m^2/day$.

The determination of the solar energy produced for this area is defined by the relationship:

$$E_{solaire} = A \times I \times T \times \eta_{ps} \text{ ………………. } (1)$$

Or :

- A : is the surface area of the photovoltaic installation estimated at (140 000 – 200 000 m^2) ;
- I : is the average solar irradiation which is in the range of 4.5 to 5 $kWh/m^2/d$ for the Forécariah area;
- T : is the number of days of sunshine per year (generally around 300 days/year) ;
- η_{ps} : is the efficiency of solar panels (usually around 15 to 20%).

The solar power estimated for this location is estimated at 20 MW.

2.4. Evaluation of the wind potential of the Forécariah area

The power curve of a wind turbine is the function that gives the power delivered by the machine as a function of the wind speed V at the center of its rotor (i.e. its hub). Its expression is:

$$P(V) = \frac{1}{2}\, \rho\, A\, C_p(V)\, V^3 \text{ ………………}(2)$$

Or :

- P : is the power delivered in W ;
- V : is the wind speed taken equal to 4.5 m/s for the Forécariah area ;
- ρ : is the density of air taken equal to 1.225kg•m−3 at sea level;
- A : is the area swept by the rotor (πR2 for a wind turbine of radius R) in m2 or R=20 m;
- cp : is the power factor (power coefficient), wind turbine characteristic.

The power factor corresponds to the proportion of the energy contained in the incident wind that the wind turbine is capable of extracting. Its theoretical maximum value is 16/27 or approximately 0.59.

3. Results and Discussion

3.1. Presentation of the results

During this study, we obtained results which we present as follows:

3.2. Results characterizing the variations of meteorological parameters

The results characterizing the meteorological parameters are summarized by sunshine, wind speed and wind rose.

Figure 1 represents the variation profile of annual sunshine in the Forécariah area over a period of 21 years (2000-2020). In this figure, we see that the maximum value was observed in 2019 and the minimum value in 2003 which are respectively 5.34 W/m^2 and 5.03 W/m^2.

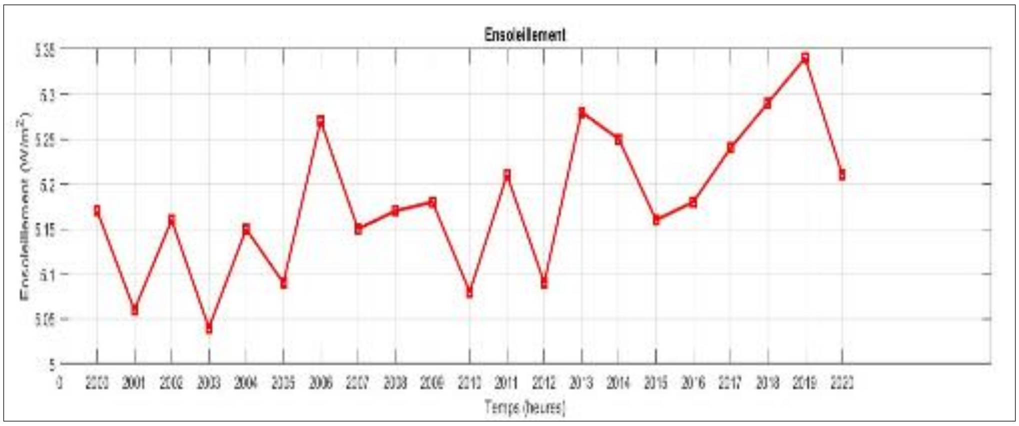

Figure 1 Annual sunshine in the Forécariah area

Figure 2 illustrates the graphical representation of the average annual speed of the Forécariah area over a period of 21 years (2000-2020). According to our analyses, we note that the maximum value was observed in 2003 and the minimum in 2010 which are respectively 3m/s and 2.6m/s.

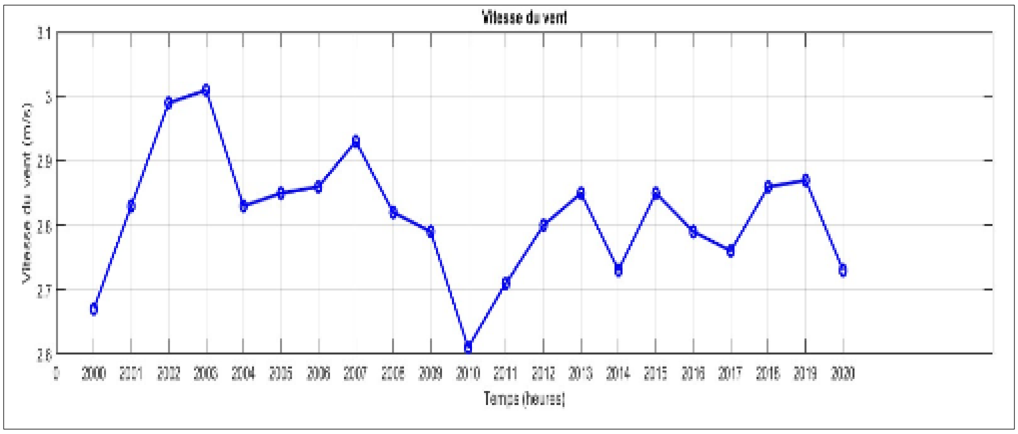

Figure 2 Average annual speed of the Forécariah area

Figure 3 shows the wind rose of the Forécariah area. This figure shows the wind direction for this location. In this figure we see that the wind is flowing from SW to NW.

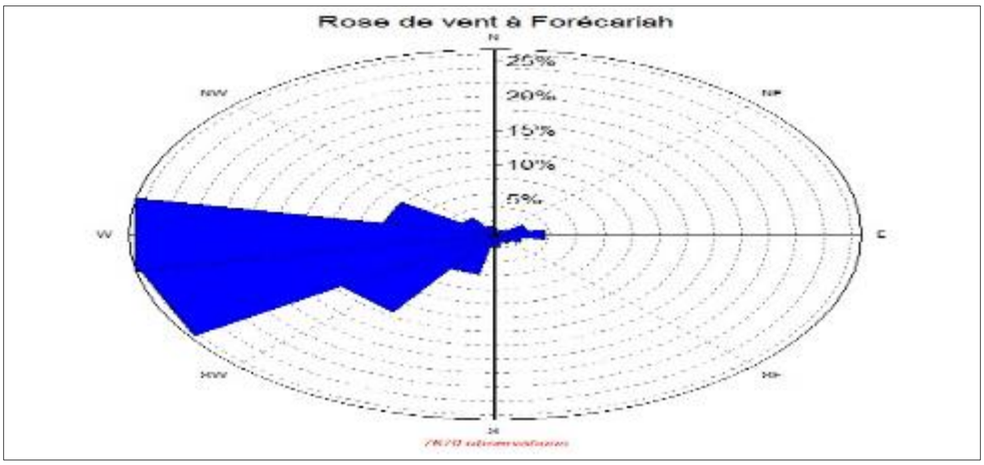

Figure 3 Wind rose of the Forécariah area

3.3. Energy potential results

The energy potential results concern solar and wind deposits in the Forécariah area. These results are recorded in Table 1.

Table 1 Results of energy potentials

N°	Parameters	Values	Unity
1	Maximum monthly sunshine	6.2	W/m²
2	Minimum monthly sunshine	3.9	W/m²
3	Maximum annual sunshine	5.34	W/m²
4	Minimum annual sunshine	5.03	W/m²
5	Maximum monthly average speed	3.8	m/s
6	Minimum monthly average speed	1.8	m/s
7	Maximum annual average speed	3	m/s
8	Minimum annual average speed	2.6	m/s
9	Power of the solar system	20	MW
10	Wind system power	2	MW
11	Number of wind turbines	82	-

3.4. Analysis of the results

According to our analyses through the results obtained during this research, we can retain:

3.4.1. Solar energy potential in Forécariah

The study of solar irradiation in the prefecture of Forécariah reveals a considerable potential for the production of solar energy. The data obtained show a maximum monthly sunshine of 6.2 W/m² and a minimum monthly sunshine of 3.9 W/m², indicating good consistency throughout the year. The results also show a maximum annual sunshine of 5.34 W/m² and a minimum annual sunshine of 5.03 W/m², which is relatively high for the region.

This level of sunshine is particularly advantageous for the production of energy from photovoltaic solar panels. Thanks to this stability, the region is able to support an installed capacity of 20 MW of solar energy, which is enough to supply a significant portion of the local population with electricity. This represents an opportunity for the Forécariah prefecture to exploit its natural resources in order to strengthen its energy independence and reduce its dependence on fossil energy sources.

3.4.2. Wind potential in Forécariah

Regarding wind potential, the wind speeds recorded in the region vary significantly. The maximum monthly average speed is 3.8 m/s, while the minimum monthly average speed reaches 1.8 m/s. On an annual basis, the maximum annual average speed is 3 m/s and the minimum annual speed is 2.6 m/s. These values indicate that the wind speed in Forécariah is relatively low, which somewhat limits the wind energy production capacity in the region.

Despite this, with the installation of 82 wind turbines, the region can still achieve a capacity of 2 MW of wind energy. This result shows that, although wind production is more modest than solar production, it can contribute to diversifying renewable energy production in the prefecture. This would allow the region to benefit from an additional source of energy, especially during periods of less sunshine.

3.4.3. Wind Direction and Wind Turbine Installation Optimization

The wind rose analysis determined that the prevailing winds blow mainly from the southwest to the northwest. This information is crucial for optimizing the installation of wind turbines, as proper orientation of the turbines relative to the prevailing winds is necessary to maximize the efficiency of energy production. By taking this orientation into account, wind turbines can be positioned to capture maximum wind energy, even in relatively moderate wind speed conditions.

3.4.4. Comparative analysis of solar and wind energy

Comparatively, solar energy has a notable advantage in terms of production in Forécariah. With a capacity of 20 MW, solar production is much greater than that of wind energy, which is limited to 2 MW. This difference is mainly due to the high solar irradiation in the region, while wind speed remains modest, thus limiting the efficiency of wind turbines. However, the interest of this study is to show that the combination of the two energy sources makes it possible to strengthen the energy resilience of the region, by diversifying energy supplies and maximizing the use of available natural resources.

3.4.5. Potential for energy infrastructure development

The assessment shows that with a combined capacity of 22 MW (20 MW solar and 2 MW wind), the prefecture of Forécariah can contribute significantly to increasing national energy production in Guinea. This renewable energy potential, if well exploited, could also attract investments in the energy sector, thereby improving access to electricity, especially in rural areas.

The stability of sunshine throughout the year makes solar energy the main source to exploit, while wind energy, although secondary, remains a viable option to supplement energy production during periods when solar is less efficient. The integration of hybrid systems, combining solar and wind, would ensure continuity in energy production, and the use of energy storage solutions could further improve this continuity.

4. Conclusion

The study conducted on the energy potential of the Forécariah prefecture reveals a strong solar potential, with stable sunshine throughout the year, making it possible to envisage large-capacity solar energy production (20 MW). The low wind speed limits the efficiency of wind systems, but with a sufficient number of wind turbines (82), a power of 2 MW can be achieved, which is a notable contribution to the region's energy mix. The orientation of the winds from the Southwest to the Northwest offers an opportunity to optimize the location of wind turbines.

In terms of outlook for this study, we plan to implement:

- Optimization of wind turbines for low wind speeds: Search for wind technologies adapted to lower wind speeds in order to maximize the efficiency of the installations;
- Development of hybrid systems: Integrate solar-photovoltaic and wind systems to compensate for the variability of each energy source;
- Energy storage capacity assessment: Study the possibility of integrating batteries or other storage systems to maximize the use of renewable energy and ensure a continuous supply of electricity;
- Environmental impact: Analyze the impact of energy installations on the local ecosystem and study solutions to minimize these impacts.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Adam Piasecki, Jakub Jurasz, Alexander Kies, Measurements and reanalysis data on wind speed and solar irradiation from energy generation perspectives at several locations in Poland, SN Applied Sciences, 2019

[2] Jurasz J, Dąbek PB, Kaźmierczak B, Kies A, Wdowikowski M (2018) Large scale complementary solar and wind energy sources cou pled with pumped-storage hydroelectricity for Lower Silesia (Poland). Energy 161:183–192. https ://doi.org/10.1016/j.energ y.2018.07.085

[3] Schlott M, Kies A, Brown T, Schramm S, Greiner M (2018) The impact of climate change on a cost-optimal highly renewable European electricity network. Appl Energy 230:1645–1659. https://doi.org/10.1016/j.apenergy.2018.09.084

[4] Andresen GB, Søndergaard AA, Greiner M (2015) Validation of Danish wind time series from a new global renewable energy atlas for energy system analysis. Energy 93:1074–1088. https://doi.org/10.1016/j.energy.2015.09.071

[5] Olauson J, Bergkvist M (2015) Modelling the Swedish wind power production using MERRA reanalysis data. Renew Energy 76:717–725. https://doi.org/10.1016/j.renene.2014.11.08

[6] Pfenninger S, Staffell I (2016) Long-term patterns of European PV output using 30 years of validated hourly reanalysis and satel lite data. Energy 114:1251–1265. https ://doi.org/10.1016/j.energ y.2016.08.060

[7] Staffell I, Pfenninger S (2016) Using bias-corrected reanalysis to simulate current and future wind power output. Energy 114:1224–1239. https://doi.org/10.1016/j.energy.2016.08.068

[8] Pfeifroth U, Sanchez-Lorenzo A, Manara V, Trentmann J, Hol lmann R (2018) Trends and variability of surface solar radia tion in Europe based on surface-and satellite-based data records. J Geophys Res Atmos 123(3):1735–1754. https ://doi. org/10.1002/2017JD027418

[9] Athina Korfiati, Charalampos Gkonos, Fabio Veronesi, Ariadni Gaki, Stefano Grassi, Roland Schenkel, Stephan Volkwein, Martin Raubal and Lorenz Hurni, Estimation of the Global Solar Energy Potential and Photovoltaic Cost with the use of Open Data, International Journal of Sustainable Energy Planning and Management, pp.17-30, 2016

[10] REN21. Renewable 2013 Glabal Status Report. 2013. http://www.ren21.net/Portals/0/documents/Resources/GSR/2013/GSR2013_highres.pdf

[11] Weinrub A. Community Power: Decentralized Renewable Energy in California. Oakland: Local Clean Energy Alliance; 2011. http://www.localcleanenergy.org/files/Community_ Power_Publication_Online-3.pdf

[12] Quiquerez L, Faessler J, Lachal BM, Mermoud F, Hollmuller P, GIS methodology and case study regarding assessment of the solar potential at territorial level: PV or thermal?, International Journal of Sustainable Energy Planning and Management 6 (2015) pages 3-16. http://dx.doi.org/ 10.5278/ ijsepm.2015.6.2

[13] Oloo FO, Olang L, Strobl J, Spatial modelling of solar energy potential in Kenya. International Journal of Sustainable Energy Planning and Management 6 (2015) pages 17-30. http://amalthea.aub.aau.dk/index.php/sepm/article/ view/ 1042

[14] Solangi KH, Islam MR, Saidur R, Rahim NA, Fayaz H, A review on global solar energy policy, Renewable and Sustainable Energy Reviews 15 (4) (2011) pages 2149-2163. http://dx.doi.org/10.1016/j.rser.2011.01.007